Moored Observations to Define the Structure and Energetics of Non-Linear Internal Wave Generation over the New Jersey Shelf

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LONG-TERM GOALS

To further our understanding of NLIW generation, to aid our NLIW prediction ability, and to quantify NLIW effects on acoustics, optics, energy dissipation, and momentum transfer in the coastal ocean.

OBJECTIVES

What environmental factors define the structure and energetics of non-linear internal wave generation, and how can theses be used to predict intensity and quality of a wave packet. Specifically:

- Under what conditions (stratification, barotropic forcing and topography) are NLIWs generated? What factors determine whether waves of elevation or waves of depression form? How are these influenced by the location of the shelf-break front?

- What are the generation mechanisms?

  1. barotropic via either a nonlinear version of Baines' (1982), or a controlled hydraulic flow which is released at low Froude numbers; or,

  2. baroclinic, whereby a nearly-linear internal tide is generated and undergoes nonlinear transformations either locally or after having propagated many wavelengths.

- What are the conversion efficiencies (i.e., the rates of energy transfer from linear to nonlinear waves, or from barotropic to baroclinic waves), and what fraction is dissipated locally? What fraction radiates away from the shelf break (forming the red beams in figure 2).

- How do the near-bottom and near-surface signatures differ for these two types of waves. How important is the bottom stress? Can a surface expression for waves of elevation be detected?

APPROACH

Moored observations are used to capture the full water column variability of density (sound speed) and velocity. From these we compute barotropic and baroclinic energy density and energy flux. Divergences of energy flux are used to assess generation location and conversion efficiencies, and phasing of baroclinic signals (and their relationship to the barotropic tide) will elucidate mechanisms.

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WORK COMPLETED

Three full water column moorings at 480-, 175- and 110-m and ADCP bottom landers were designed, deployed and recovered during the SW06 experiment over the New Jersey shelfbreak. These resolved the full-water column dynamics (using closely spaced CTD measurements and multiple ADCPs per mooring) and were positioned to capture the generation region for nonlinear internal waves. These compliment WHOI's SW06 mooring effort (Lynch, Irish & Duda) which was positioned to observe wave propagation.

50-day records of rapidly-sampled velocity and vertical displacement were obtained, enabling baroclinic and barotropic energetics to be computed for the duration of the SW06 experiment. These permit NLIW energetics to be evaluated (Nash et al 2005, Moum et al 2006) and conversion efficiencies to be computed. These calculations will yield the partitioning between linear and nonlinear internal wave energy input onto the New Jersey Shelf and provide the offshore grounding to support inshore process experiments.

Moorings were recovered in mid September, 2006, so the following represents a preliminary view of the data.

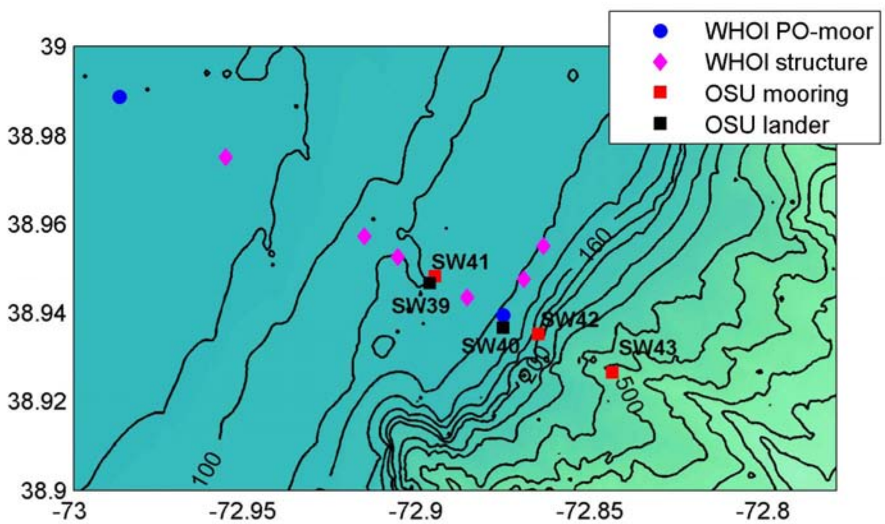

Figure 1: Coordinated placement of OSU water-column moorings (SW41-43) and bottom landers (SW39-40) capture the generation region at the New Jersey shelf break.

RESULTS

These mooring observations were highly successful in capturing the offshore boundary condition. As anticipated, motions over the 500-m isobath are highly baroclinic (Fig 2) and contain variability at many timescales, suggesting that shelfbreak conditions cannot be predicted from barotropic tidal models alone. The observations capture near-inertial and mesoscale variability associated with the shelf-break front and Gulf Stream influences.

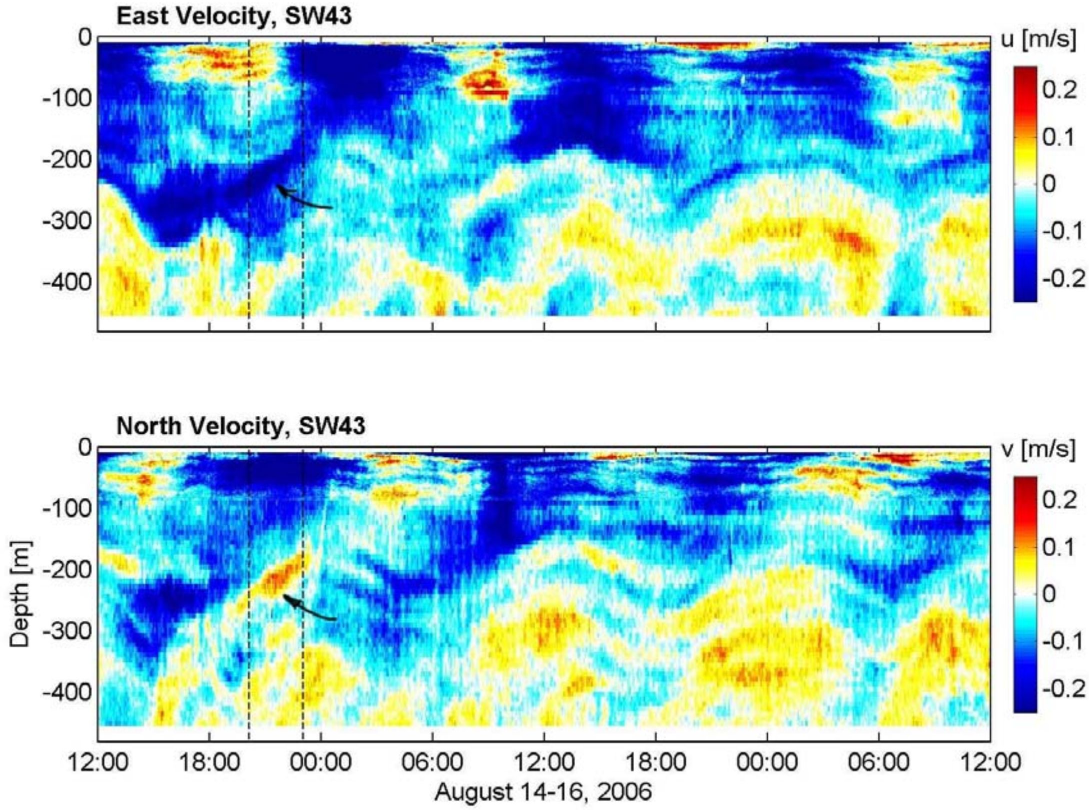

Figure 2: A typical 48-h timeseries of velocity at SW43 (480-m water depth; data from 75 and 500 kHz ADCPs has been merged to span the full water column.) The dominant variability is highly baroclinic, semidiurnal, and at many vertical wavenumbers. Also evident are large semidiurnal displacements of pre-existing shear at 200-400 m depths. Dashed lines represent the time period shown in Fig. 3; the arrow points to a northwestward flow common to both locations.

A preliminary analysis indicates features can be tracked from a pre-wave-like to fully nonlinear state. One such example is shown in figures 2 and 3, where NLIWs at station SW40 (Fig. 3) appear to be excited by the strong baroclinic tide observed at SW43 (Fig. 2). This produces a packet of waves of elevation with large vertical velocities ahead of a northwestward near-bottom flow, similar to the wave fission Nash and Moum (2005) observed from the Columbia River plume front. We are encouraged that our energy flux calculations will elucidate wave generation mechanisms and propagation dynamics.

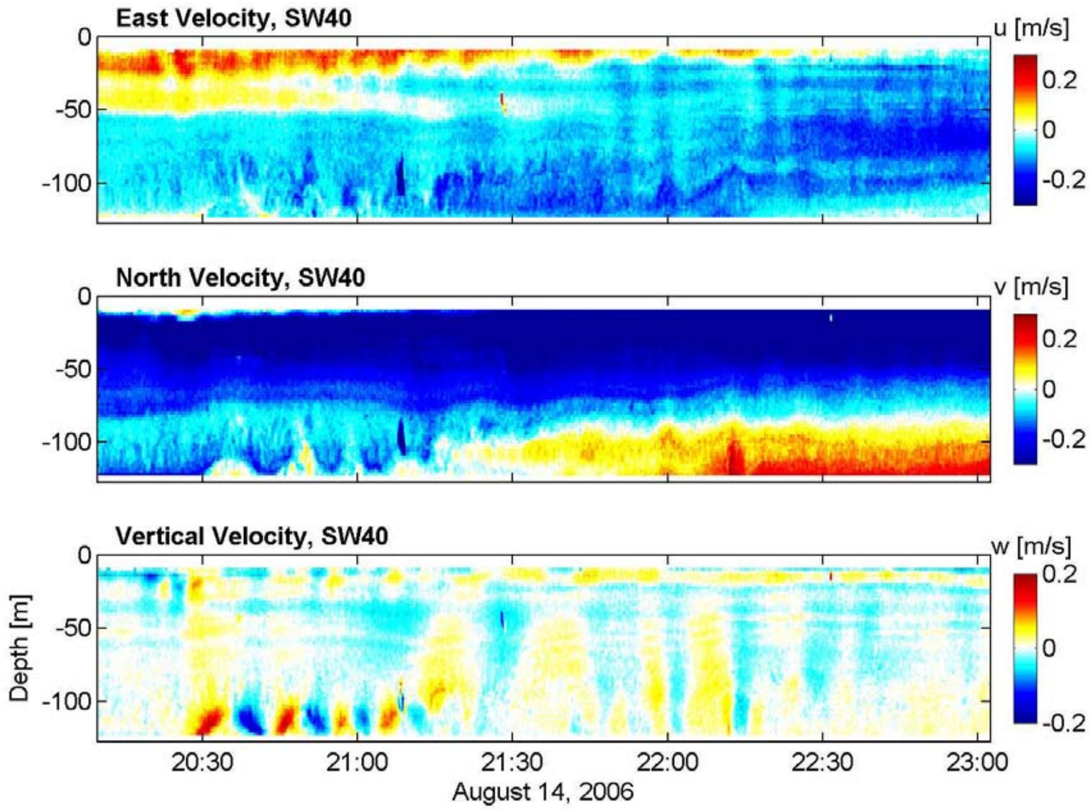

Figure 3: A 3-h time series of velocity at SW40 (130-m depth) for time period indicated by dashed lines in Fig. 2. Here, a northwestward pulse of fluid at 100-m depth appears to excite a packet of waves of elevation ahead of the pulse (evident in the alternating bands of 20 cm/s vertical velocity near the bottom at 20:30). The beginnings of near-surface waves of depression are also evident. The northwestern-propagating pulse appears to be the same as that observed at 200-m depth several kilometers offshore (at SW43; small arrows in Fig. 2) and also captured at SW42 (not shown).

IMPACT/APPLICATION

This analysis will provide the physical understanding of mechanisms so NLIW occurrence and propagation characteristics can be predicted at this location. This will lead to a general understanding of processes to aid NLIW prediction elsewhere.

RELATED PROJECTS

These observations are part of a coordinated effort to define the structure and timing of the signals that emerge from the interaction of the stratification with the shelf break for other DRI participants. This data will define the energy flux of NLIWs entering the shelf, and be used to estimate propagation speeds, etc.

In addition, a combination of long and short-term programs on the New Jersey shelf (initiated by personnel at Rutgers University, the CoOP-sponsored LATTE program, LEAR and AWACS) includes inshore moorings in the region, gliders to the shelf breaks, AUV observations, and surface velocity

from 100 nm CODAR coverage. These projects are highly synergistic and will be used to study a wide variety of physical, biological and acoustic properties of the region.

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